

# Harvest Potential and Management of American Black Ducks

## *Progress Report*

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## **Introduction**

Management of American black ducks (*Anas rubripes*) has long been hampered by a lack of understanding regarding the factors affecting changes in annual abundance. This has resulted in disagreements among stakeholders about whether to use hunting regulations to arrest the large-scale decline of black ducks, and ultimately how to provide sustainable hunting opportunities. In 1999 a technical working group was formed to investigate how the U.S. and Canada might cooperate in an adaptive approach to black duck harvest management. Adaptive harvest management (AHM) for black ducks is viewed as a means of dealing with (rather than resolving) uncertainties in population and harvest dynamics, particularly those concerning the role of mallard competition and sport harvest in the long-term decline in black duck abundance.

Working under contract, the U.S.G.S. Cooperative Fish and Wildlife Research Unit in Georgia has been leading the technical effort to develop an international AHM framework for black ducks. The effort has produced quantitative models that codify the most controversial hypotheses concerning black duck population dynamics (Conroy et al. 2002), and for the first time has provided a rigorous analytical framework with which to explore the implications of harvest-management policy. However, the effort to develop an international framework for black duck AHM is ongoing and a date for implementation remains uncertain.

In 2003, we began working with the Atlantic Flyway Council and others to develop an assessment framework that could be used to better inform black duck harvest management in the U.S. in the interim. This framework is intended to help the Fish and Wildlife Service assess the biological implications of any proposed changes to hunting regulations, as well as complement the ongoing effort to develop an AHM program for black ducks.

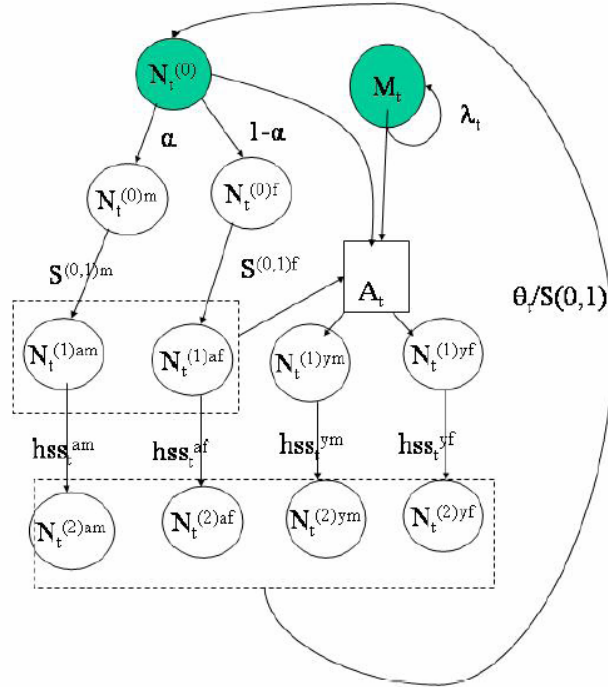
Herein we report on our progress in developing this assessment framework. Our objectives were:

- 1) to estimate harvestable surpluses of black ducks, and to determine how these surpluses might vary over time;

- 2) to review black duck harvest-management policy in the U.S., and its consequences in terms of realized harvest rates; and
- 3) to discuss some of the ongoing activities to develop a more informed and robust harvest strategy for black duck.

### Population Dynamics of Black Ducks

We relied on the models of population dynamics as based on midwinter surveys (MWS) that were developed by Conroy et al. (2002). The model of the annual cycle is depicted in the following diagram, and is described in the subsequent narrative.



In any given year we take as our initial population size the total numbers of breeding black ducks  $N_t^{(0)} = N_t$ . This is partitioned into male and female components (not observable in the MWS) as

$$\begin{aligned} N_t^{(0)m} &= P_m N_t^{(0)} \\ N_t^{(0)f} &= (1 - P_m) N_t^{(0)} \end{aligned} \quad (1)$$

where  $P_m = 0.545$  is an assumed stable proportion of males, estimated from band recovery data (Conroy et al. 2002). A reproduction model is parameterized by

$$\log[\tilde{A}(i)_t] = \beta_0(i) + \beta_1(i)N_t^{(0)} + \beta_2(i)M_t^{(0)} + 32\beta_3(i), i = 1, 2 \quad (2)$$

under alternative hypotheses of the absence ( $i = 1$ ) and presence ( $i = 2$ ) of mallard (*M. Anas platyrhynchos*) competition, where  $A_i(i)$  is predicted fall age ratio (juvenile to adults) under each alternative model. The coefficients used in the respective models are

$$\begin{aligned}\underline{\beta}(1) &= \{.975777582, -0.162742982, 0, -0.01285263\}, \text{ and} \\ \underline{\beta}(2) &= \{1.235189018, -0.133553341, -0.095895149, -0.014388189\}\end{aligned}\quad (3)$$

The last coefficient  $\beta_3$  is added to account for a linear decreasing trend in age ratio unexplained by habitat or other factors, with the prediction equation calibrated to 1993 (year 32 of the data set; Conroy et al. 2002). Coefficient estimates were obtained by fitting historical data on age ratios, estimated from harvest data, to MWS data for black ducks and mallards. Maximum likelihood estimates of coefficients were obtained under each alternative model, and AIC was used to compute model weights under each alternative reproduction model of  $wt_p(1) = 0.000585$  and  $wt_p(2) = 0.999415$  under the no competition and competition models, respectively (Conroy et al. 2002). Fall population sizes just prior to the hunting season for black ducks were projected by

$$\begin{aligned}N_t^{(1)am} &= N_t^{(0)m} S_t^{(0,1)m} \\ N_t^{(1)af} &= N_t^{(0)f} S_t^{(0,1)f} \\ N_t(i)^{(1)ym} &= N_t(i)^{(1)yf} = [N_t^{(1)am} + N_t^{(1)af}] \tilde{A}(i) \times 0.5 \\ i &= 1(\text{no competition}), 2(\text{competition})\end{aligned}\quad (4)$$

where  $S_t^{(0,1)f} = 0.75$  was assumed and  $S_t^{(0,1)m} = S_t^{(0,1)f} * (\alpha / (1 - \alpha))$  with  $\alpha = 0.545$  estimated from band recovery data (Conroy et al. 2002).

Harvest of ducks is determined via decision variables (see below), which are specified as harvest rates for adult male black ducks in Canada ( $h_t^{Can}$ ) and the U.S. ( $h_t^{US}$ ), respectively; this differs from the development in Conroy et al. (2002) in which the harvest rates were aggregated across both the U.S. and Canada into a single rate. These harvest rates are in terms of harvest of adult males, extended to the other age-sex classes by means of differential vulnerability coefficients as

$$\begin{aligned}h_t^{k,am} &= h_t^k \\ h_t^{k,af} &= h_t^k d^{af} \\ h_t^{k,ym} &= h_t^k d^{ym} \\ h_t^{k,yf} &= h_t^k d^{yf} \\ k &= Can, US\end{aligned}\quad (5)$$

The coefficients were estimated from band recovery data (Conroy et al., 2002) as

$$\underline{d} = \{1, 0.94, 2.03, 1.88\}\quad (6)$$

The age- and sex-specific, regional harvest rates were then adjusted by crippling loss to compute age- and sex-specific harvest mortality rates for harvest in Canada and the U.S. as

$$K_t^{k,m} = h_t^{k,m} / (1 - c) \quad (7)$$

$$k = Can, US; \quad m = 1, 2, 3, 4 (am, af, ym, yf)$$

where  $c = 0.2$  was taken as a constant, assumed rate of crippling loss (Conroy et al. 2002). Survival over the combined hunting seasons (Canada and the U.S.) were used to calculate winter population sizes for each age-sex class, under each competition model, as

$$N_t(i)^{(2)m} = N_t^{(1)i} \times hss_t^m \quad (8)$$

$$m = 1, 2, 3, 4 (am, af, ym, yf)$$

where

$$hss_t^m = (1 - K_t^{1,m})(1 - K_t^{2,m}) \quad (9)$$

Winter population size was aggregated across age-sex classes to compute total abundance as

$$N_t(i)^{(2)} = \sum_m N_t(i)^{(2)m} \quad (10)$$

$$i = 1, 2; \quad m = 1, 2, 3, 4$$

This value is in turn used to predict winter survival under alternative models of density-independent ( $j = 1$ ) and density-dependent ( $j = 2$ ) mortality as

$$\text{logit}[\tilde{\theta}(i, j)_t] = \alpha_0(j) + \alpha_1(j)N_t(i)^{(2)} \quad (11)$$

$$i = 1, 2; \quad j = 1, 2$$

The coefficients used in the respective models are

$$\underline{\alpha}(1) = \{1.033288, 0\} \quad (12)$$

$$\underline{\alpha}(2) = \{1.033288, -0.000001\}$$

Corresponding to each model are estimated AIC weights of  $wt_s = \{0.881, 0.119\}$ ; see Conroy et al. (2002) for details of the empirical basis for these estimates and model weights.

These survival predictions were used to project winter populations to the subsequent breeding population by

$$N_{t+1}(i, j)^{(0)} = [N_t^{(2)am} + N_t^{(2)ym}] \tilde{\theta}(i, j)_t / S^{(0,1)m} + [N_t^{(2)af} + N_t^{(2)yf}] \tilde{\theta}(i, j)_t / S^{(0,1)f} \quad (13)$$

under each combination of reproduction ( $i = 1, 2$ ) and survival ( $j = 1, 2$ ) model. Finally, a weighted average projection was produced as

$$\overline{N_{t+1}^{(0)}} = \sum_{i=1}^2 \sum_{j=1}^2 wt_p(i)wt_s(j)N_{t+1}(i,j)^{(0)} \quad (14)$$

Calibration of this model to historical data (Conroy et al., 2002) indicated positively biased prediction in most years. Because we did not know the process(es) underlying this bias, we used least-squares approaches to minimize prediction error by incorporating adjustment factors into the model used to predict  $N_{t+1}$ . We incorporated adjustments into two model components of the model. One candidate adjustment was on recruitment, by modifying (4) as

$$N_t(i,1)^{(1)ym} = N_t(i)^{(1)yf} = [N_t^{(1)am} + N_t^{(1)af}] \tilde{A}(i) \times 0.5 \times \xi_1 \quad (15)$$

This adjustment carries through remaining events (harvest, winter survival), to provide a modified prediction under each reproduction and survival model of

$$N_{t+1}(i,j,1)^{(0)} \quad (16)$$

The other candidate adjustment was on post-winter survival, modifying (13) as

$$N_{t+1}(i,j,2)^{(0)} = N_{t+1}(i,j)^{(0)} \times \xi_2 \quad (17)$$

Least-squares analysis (Conroy et al., 2002) provided estimates of  $\xi = \{0.588, 0.798\}$  and AIC weights under each adjustment of  $wt_{adj} = \{0.49, 0.51\}$ . These values were used to provide adjusted, model-averaged estimates over the two reproduction, two survival, and two adjustment models according to (Fig. 1):

$$\overline{\tilde{N}_{t+1}^{(0)}} = \sum_{i=1}^2 \sum_{j=1}^2 \sum_{k=1}^2 wt_p(i)wt_s(j)wt_{adj}(k)N_{t+1}(i,j,k)^{(0)} \quad (18)$$

We computed residuals from 1961-93 MWS estimates of  $N_t$  as

$$R_t = N_t - \overline{\tilde{N}_t^{(0)}} \quad (19)$$

We transformed these residuals to a log scale and computed a mean and standard deviation over 1961-93, and used these statistics to generate quantiles from a normal distribution with these parameters. These quantities were back-transformed to compute a discrete random variable, whose outcomes were multiplied by predictions from the state dynamics (18), resulting in random outcomes for  $N_{t+1}$ .

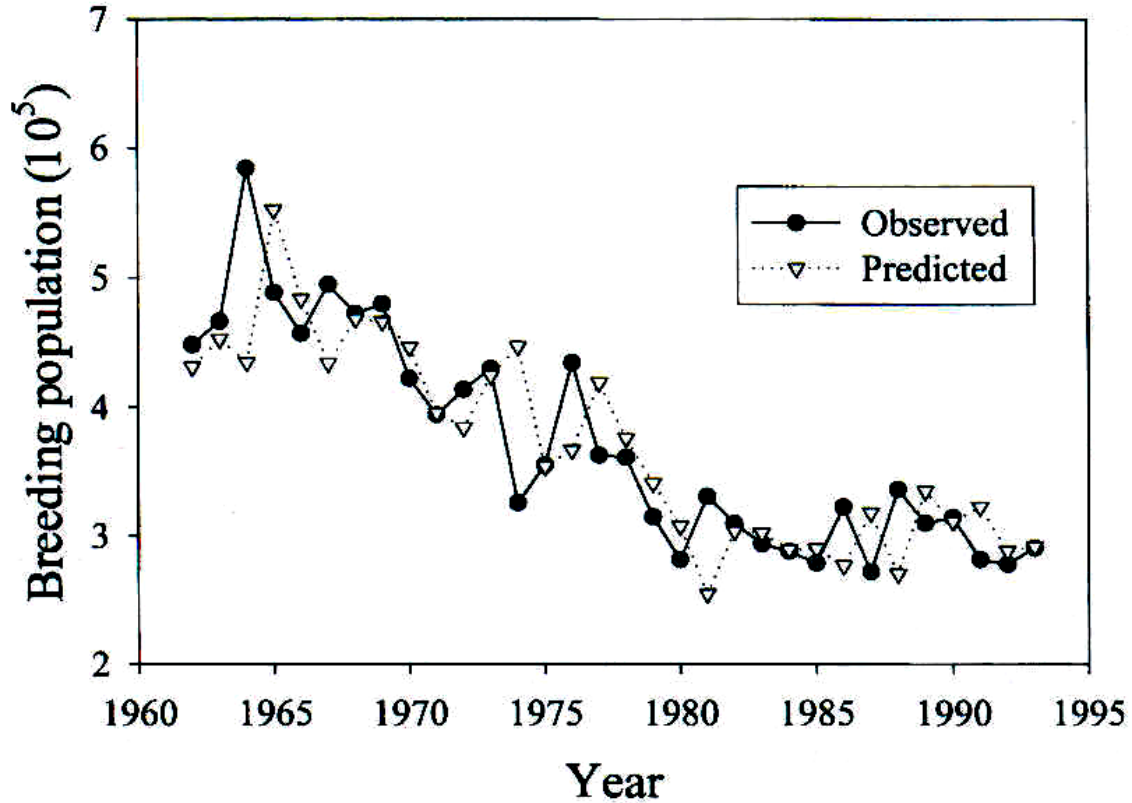


Fig 1. Predictions under the model-averaged forecasting model (equation 18) and abundance of breeding black ducks as indexed by midwinter waterfowl surveys, 1962-93 (Conroy et al. 2002).

We also had to incorporate a dynamic model for mallards because their abundance affects the reproductive rates of black ducks. Mallard abundance was indexed by counts from the MWS in the Atlantic Flyway, and from the states of Wisconsin, Michigan, Indiana, Ohio, Kentucky, and Alabama, which derive most of their mallard harvest from the black duck breeding range (Conroy et al. 2002). We initially attempted to fit logistic growth models to the trajectory of MWS data for mallards. We abandoned these efforts after discovering little evidence of a sigmoid growth pattern; instead, our examination of the MWS data suggested a model of the form

$$M_{t+1} = M_t \times \lambda_t \quad (20)$$

with  $\lambda_t$  highly variable but averaging  $\bar{\lambda} = 1.002$ . We used estimates of  $\lambda_t = M_{t+1}/M_t$  from the MWS data over 1971-1994 to obtain an empirical distribution, which was then discretized to specify random outcomes for  $M_{t+1}$ .

### Harvest Potential of Black Ducks

The harvest of renewable natural resources is predicated on the theory of density-dependent population growth (Hilborn et al. 1995). This theory predicts a negative relationship between the intrinsic rate of population growth and population density (i.e., number of individuals per unit of

limiting resource) due to intra-specific competition for resources. In a relatively stable environment, un-harvested populations tend to settle around an equilibrium where births balance deaths. Populations respond to harvest losses by increasing reproductive output or through decreased natural mortality because more resources are available per individual. Population size eventually settles around a new equilibrium and the harvest, if not too heavy, can be sustained without destroying the breeding stock. Resource managers typically attempt to maximize the sustainable harvest by driving population density to a level that maximizes the intrinsic rate of population growth (Beddington and May 1977).

We were thus interested in ascertaining how equilibrium population size and harvest of black ducks vary as a function of adult harvest rate. We conducted a series of deterministic simulations of population dynamics using the average model provided in equation (18). Each simulation used the same initial numbers of black ducks (300 thousand), a fixed number of mallards, and a fixed harvest rate of adult black ducks. Each simulation was run until the black duck population reached equilibrium (typically within 100 iterations). We then plotted combinations of black duck equilibrium population sizes and harvests for each level of mallards and for the range of black duck harvest rates we examined.

We calculated equilibrium population sizes and harvests for adult black duck harvest rates from 0.0-0.20 in increments of 0.025. For purposes of these simulations, we examined three fixed levels of mallards: 249 thousand and 479 thousand, which were the 5<sup>th</sup> and 95<sup>th</sup> percentile, respectively, from the 1961-2003 MWS, and 395 thousand, which was the mean count during 1994-2003. Equilibrium population size in the absence of harvest (i.e., carrying capacity) ranged from a low of 501 thousand to a high of 649 thousand as the number of sympatric mallards decreased (Fig. 2). The harvest rate that produced the maximum sustained yield (MSY) varied from 0.07-0.1, but the size of the MSY varied two-fold between extreme numbers of mallards. The equilibrium population size associated with the MSY was below the goal of the North American Waterfowl Management Plan (NAWMP) in all cases, suggesting that current environmental conditions are insufficient to support MSYs at the NAWMP goal. A fixed harvest rate of 0.2 was sufficient to extirpate black ducks in all cases.

We next relaxed the assumptions of a deterministic environment and fixed numbers of mallards to determine a state-dependent harvest policy. Such a policy prescribes an optimal harvest rate for adult black ducks each year, conditioned on the numbers of black ducks and mallards observed in the MWS. We used stochastic dynamic programming (SDP; Lubow 1995) to determine a state-dependent policy using the black duck and mallard dynamic models described previously, and a basic management objective to maximize the long-term cumulative sum of black duck harvests. The policy is sensitive to the observed number of black ducks, but much less so to the number of mallards (Fig. 3). We believe this may be an artifact of our rather simplistic mallard model, in which mallard numbers in any given year are not very informative of mallard numbers in successive years. SDP accounts for not only current system states and harvest returns in the calculation of optimal decisions, but for all future states and returns as well. In any case, assuming that the dynamics of black ducks and mallards are represented reasonably well by our models, implementation of this policy would be expected to result in an average

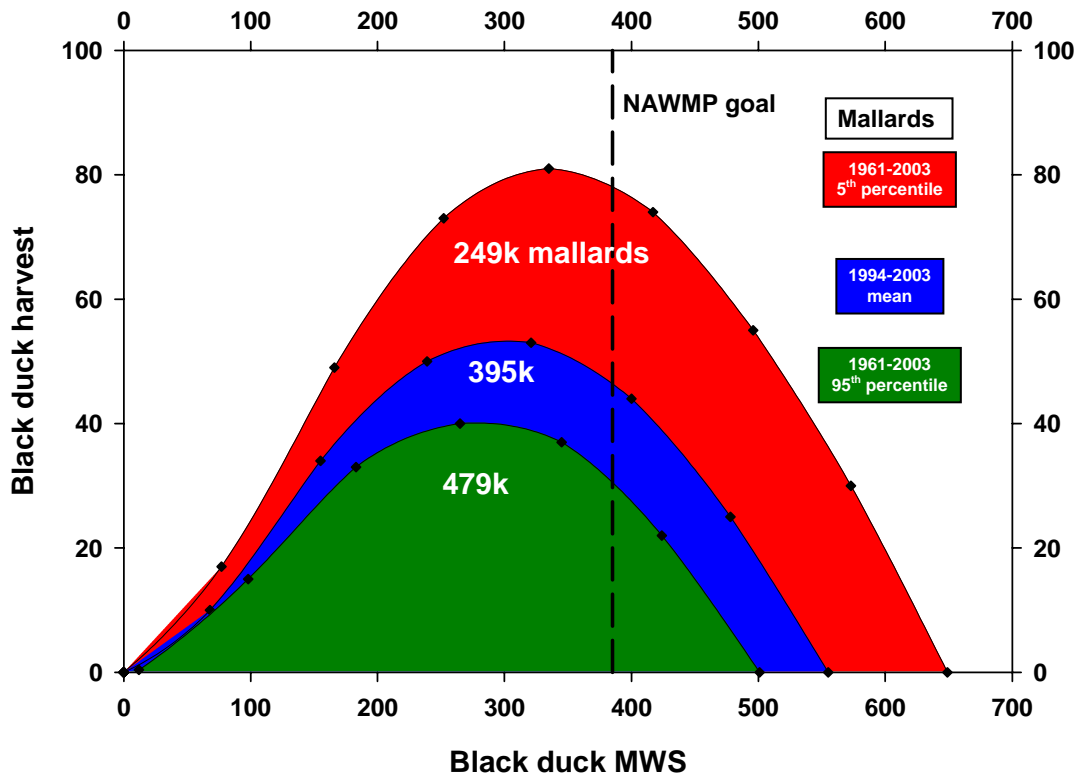


Fig 2. Equilibrium population sizes and sustainable harvests for a range of fixed adult harvest rates (increasing from right to left from 0.00 to 0.20 in increments of 0.025) and for fixed numbers of sympatric mallards. The North American Waterfowl Management Plan (NAWMP) goal is 385 thousand black ducks in the MWS. The goal has recently been translated into a breeding population goal, although it retains the historic relationship between MWS and breeding survey counts (as based on Canadian Wildlife Service surveys).

black duck population of about 305 thousand (SD = 84 thousand), subject to an average adult harvest rate of 0.11 (SD = 0.07).

As described on page 3, there is a linear decreasing trend in fall age ratios of black ducks that cannot be accounted for by variation in the abundance of black ducks or mallards. The cause is unknown, but may be related to declines in the quantity and/or quality of breeding or wintering habitat or both (Conroy et al. 2002). There is also some information suggesting that the decline may be widespread on the breeding grounds (Eric Reed, Canadian Wildlife Service, pers. comm.). For the previous analyses, we assumed that the reproductive capacity of black ducks was that supported by environmental conditions extant in 1993 (equation 2). To understand the management implications of the declining trend in productivity, we conducted a series of deterministic simulations similar to those described previously to calculate equilibrium population sizes and harvests for three periods: 1980-1984, 1990-1994, and 200-2004. For each period, we set the coefficient  $\beta_3$  (equation 2) to correspond to the median year, and initialized each simulation with the observed, average numbers of black ducks and mallards. Mallard numbers were fixed throughout each simulation, and each simulation was run with a fixed

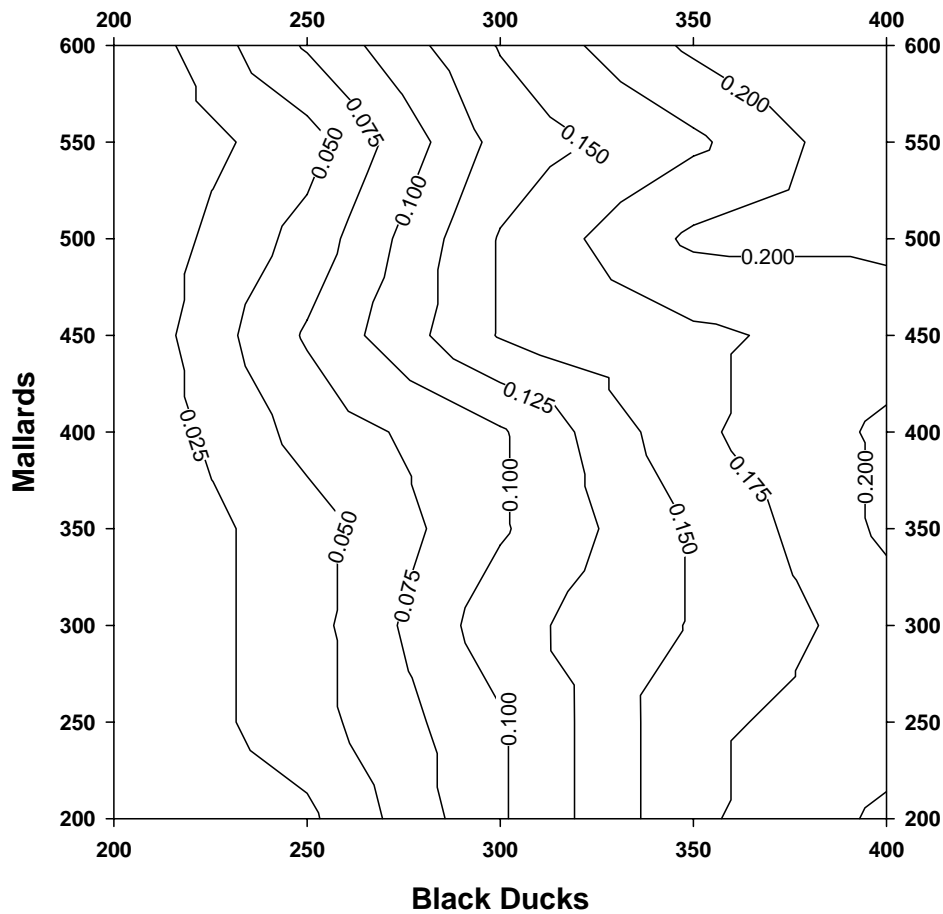


Fig. 3. Optimal harvest rates of adult black ducks each year conditioned on the observed numbers of black ducks and mallards (in thousands) in the MWS. The harvest management objective of this policy is to maximize the cumulative sum of black duck harvests over the long term.

harvest rate from 0.00 to 0.20 in increments of 0.05. Combinations of equilibrium population sizes and harvests for each period were plotted as before. We note that the calculations for the 2000-2004 period represent an extrapolation of approximately a decade beyond the limits of the available data and therefore should be interpreted with caution.

If the apparent decline in productivity is real and has continued to the present, it could be responsible for a reduction in black duck carrying capacity from 681 thousand during 1980-1984 to 444 thousand during 2000-2004, a decline of 35% (Fig. 4). The decline in MSY could be even more dramatic, decreasing by more than 60% over the last 20 years. A sustained adult harvest rate of 15% may now be capable of extirpating the black duck population.

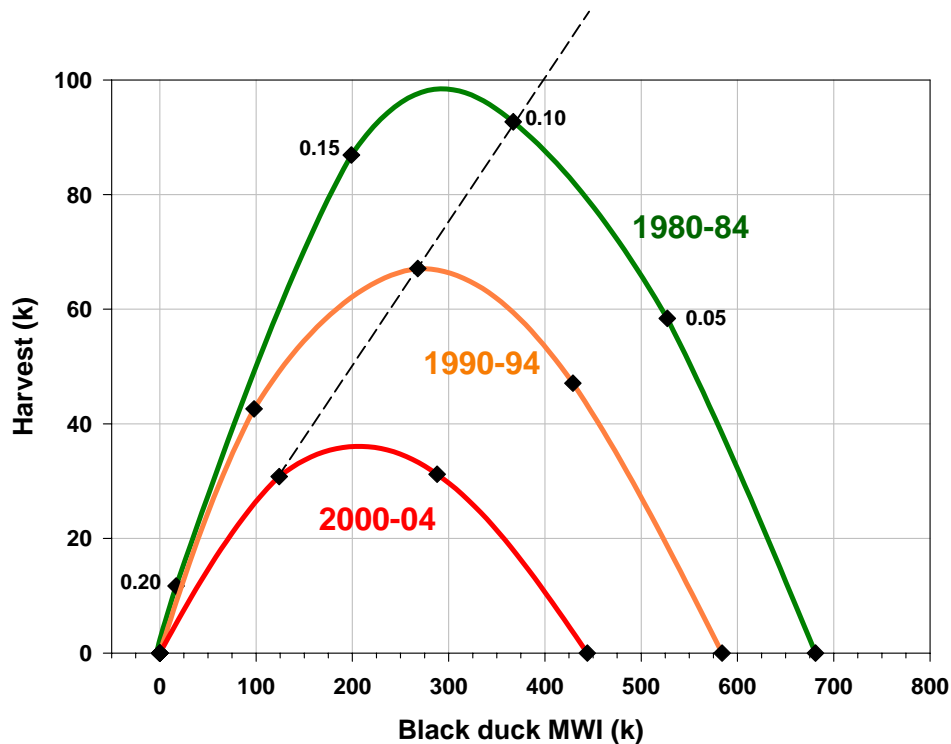


Fig. 4. Collapsing equilibrium population sizes and sustainable harvests as a result of declining reproductive rates in black ducks. The three time periods represent their respective averages in terms of observed mallard abundance and black duck productivity. The dotted diagonal line represents an adult harvest rate of 0.1 on each yield curve.

## Harvest Management Policy

Following a 25-year decline in the abundance of black ducks as measured by the MWS, the Fish and Wildlife Service issued an Environmental Assessment (EA) in 1983 calling for further restrictions on the sport harvests of black ducks. As a result of the EA the Fish and Wildlife Service reduced the daily bag limit to one black duck in the Mississippi Flyway, and permitted a variety of regulatory options in the Atlantic Flyway, including shorter seasons, delayed season openings, and bag-limit restrictions, which were designed to reduce the Flyway harvest by 25%. States in the Atlantic Flyway were free to choose the combination of restrictions that best suited their needs, and by 1994 collectively they had achieved a 47% reduction in Flyway harvest. With the implementation of AHM for general duck seasons in 1995, most states in the Atlantic Flyway gradually returned to the maximum season length allowable under framework regulations, although a daily bag limit of one black duck has been maintained through federal regulations. By 1994, the Mississippi Flyway had achieved a 45% reduction in black duck harvest solely through the bag-limit restriction. Since 1994, harvests have remained at comparable levels. Black duck harvest in Canada has declined at an average rate of 3% per year since record keeping began in 1968, in part due to regulatory restrictions but probably more as a result of their dramatic long-term decline in hunter numbers.

The shortcoming of the EA was that harvests could be expected to decline irrespective of regulatory restrictions due to declines in black duck population size and hunter numbers in Canada and the eastern U.S. However, harvest rates also appear to have declined over most of the period of record (Fig. 5). In part this may be due to restrictions that were being gradually implemented prior to the EA in 1983. However, harvest rates appear to have increased concurrent with implementation of AHM in 1995 and the gradual lengthening of hunting seasons in the Mississippi and Atlantic Flyways from 30 days in 1993 to 60 days in 1997-2004.

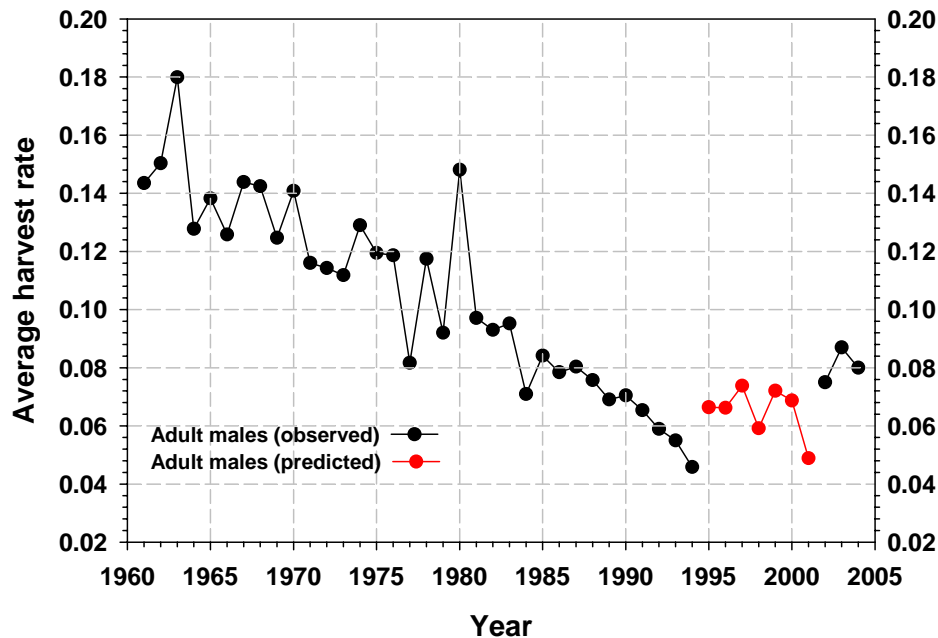


Fig. 5. Harvest rates of black ducks averaged over all banding reference areas for 1961-1994 (Conroy et al. 2002). Rates during 1995-2001 are predictions based on the historic relationship between harvest rates, U.S. harvests, and MWS counts:  
 $\text{logit}(\text{harvest rate}) = -5.01 + 4.38(\text{harvest}/(\text{harvest} + \text{MWS}))$ ;  $F_{25}^1 = 19.37$ ;  $P = 0.0002$ ;  $R^2 = 0.44$ .  
 Rates during 2002-2004 were estimated directly from pooled banding and recoveries of \$100 reward bands.

Harvest management objectives of black ducks have always been somewhat ambiguous, in that they have not been derived from a synthetic assessment of black duck population dynamics (and associated harvest potential), nor have performance criteria been articulated in a way that could identify a unique harvest policy. Nonetheless, a retrospective look at observed harvest rates, in combination with our models of population dynamics and SDP (Lubow 1995), allows one to infer at least the implicit objectives of black duck harvest management since the early 1960s.

During 1961-94, observed harvest rates (Conroy et al. 2002) generally were consistent with those designed to achieve an objective to maximize long-term cumulative harvest, subject to a population constraint equivalent to the NAWMP goal of 385 thousand black ducks in the MWS (Fig. 6). Had this harvest policy been in place, the population constraint would have acted in a way to avoid harvest-rates that resulted in black duck populations below the NAWMP goal by

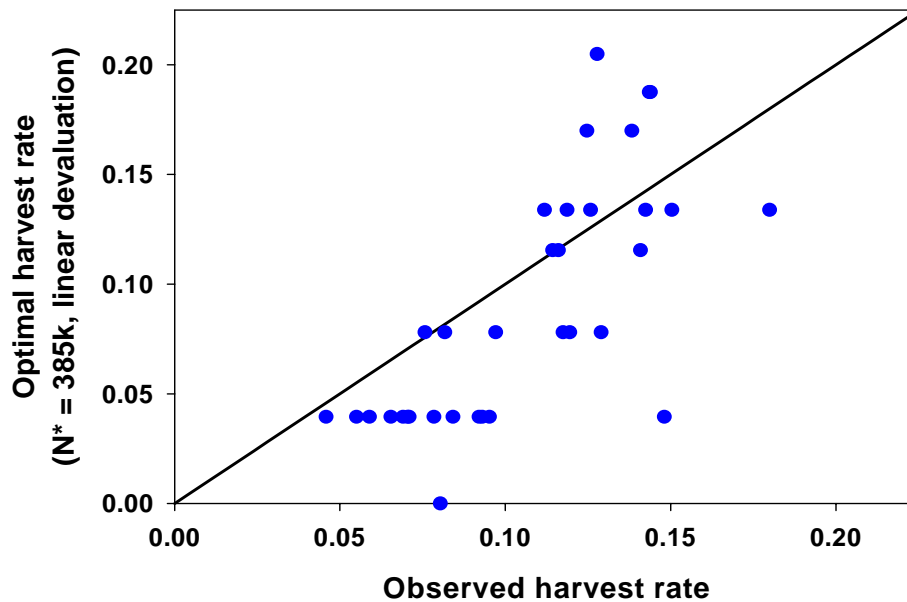


Fig. 6. Observed harvest rates of adult black ducks during 1961-94 compared to what would have been optimal under an objective to maximize long-term cumulative harvest, subject to a population constraint equivalent to the NAWMP goal of 385 thousand in the MWS. The diagonal line represents perfect correspondence between optimal and observed rates.

devaluing their associated harvests (similar to the current objective function for mid-continent mallard AHM). The period when black duck harvest rates most consistently diverged from this objective was in the early to mid 1980s, when harvest rates were higher than optimal. This was just prior to the regulatory restrictions that were enacted as a result of the EA in 1983

We also examined black duck harvest rates as estimated from pooled bandings and recoveries of \$100 reward bands during 2002-2004 (Fig. 7), and compared them with what would have been optimal using a state-dependent harvest policy derived under three different harvest management objectives. Those objectives were:

- 1) to maximize long-term cumulative harvest;
- 2) to maximize long-term cumulative harvest, subject to a population constraint of 385 thousand in the MWS using a linear (proportional) devaluation of harvest (Fig. 8) (i.e., the historic management objective described above); and
- 3) to maximize long-term cumulative harvest, subject to a population constraint of 298 thousand in the MWS (the equivalent of the 1996-1999 average of the Canadian Wildlife Service breeding-ground surveys) using a nonlinear (convex) devaluation of harvest (Conroy et al. 2004); this objective was recommended for consideration by the international Black Duck AHM Working Group.

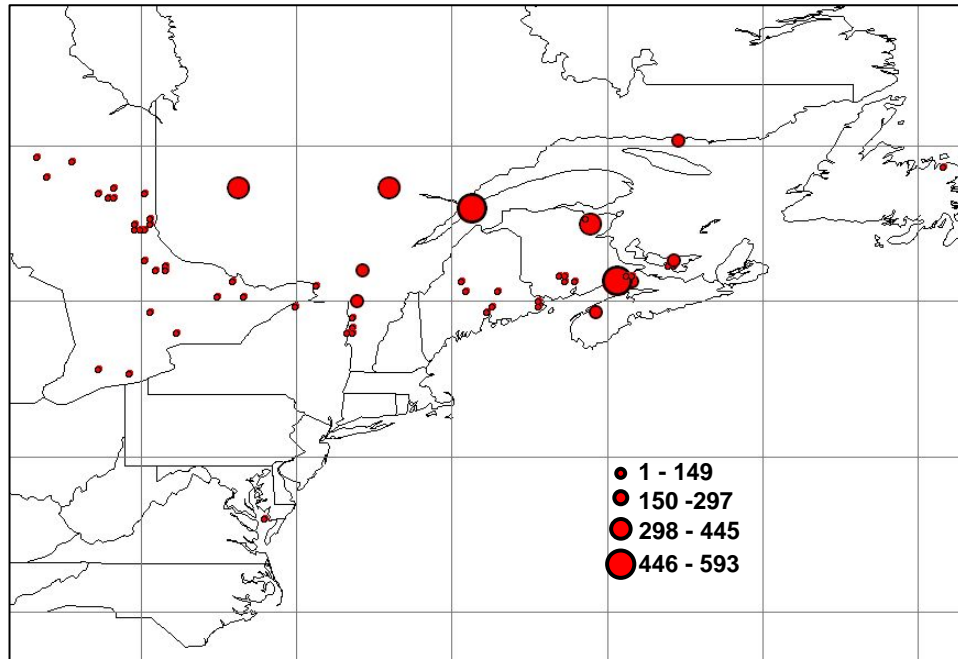


Fig. 7. Distribution of \$100 reward bands placed on black ducks prior to the hunting season in 2003. The distribution of banding in 2002 and 2004 was similar to that shown here.

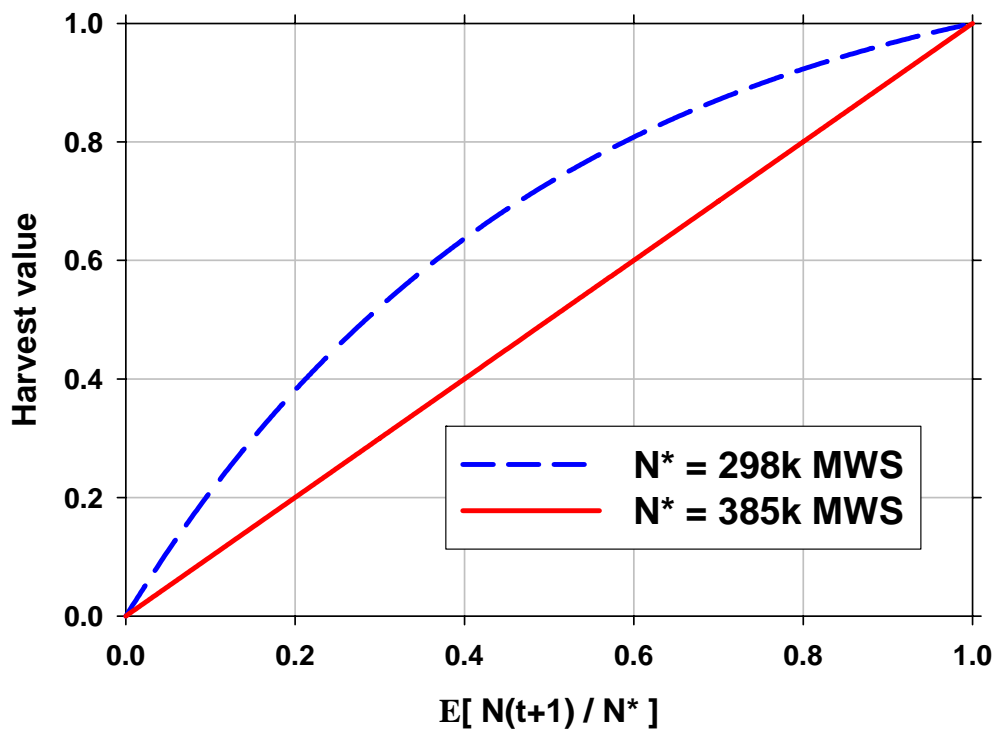


Fig. 8. Harvest value (with a value of 1.0 equivalent to full value) relative to two different population goals ( $N^*$ ) for black ducks in the midwinter survey (MWS).

Optimal harvest rates appear to be sensitive to small changes in the abundance of black ducks, which probably are not measured well by the MWS (Table 1). Estimated harvest rates exceeded what would have been optimal under all three management objectives in both 2003 and 2004. We hasten to add, however, that although harvest rates (0.08 – 0.09) in the last two years may have been above optimal for the management objectives we examined, it does not necessarily mean they are unsustainable. For example, a previous analysis suggested that an adult harvest rate of 0.11 on the average is necessary to maximize long-term cumulative harvest, and higher rates may be sustainable although they would result in lower average harvests and population sizes than those associated long-term cumulative harvests. We strongly caution the reader, however, that this conclusion does not take into account any declines in black duck productivity that may have occurred after 1993.

Table 1. Observed harvest rates of adult black ducks (h) as estimated from pooled bandings and recoveries of \$100 reward bands, compared to what would have been optimal under three different management objectives (described in the text). Optimal rates are conditioned on the models of population dynamics described by Conroy et al. (2002).

Year	Black duck MWI*	Mallard MWI*	Observed	Optimal harvest rate, under objective to:		
			h (se)	maximize long-term cumulative harvest	maximize harvest + pop. goal = 298k (nonlinear harvest devaluation)	maximize harvest + pop. goal = 385k (linear harvest devaluation)
2002	300k	550k	0.075 (0.010)	0.13	0.12	0.04
2003	250k	300k	0.087 (0.012)	0.04	0.02	0.00
2004	250k	350k	0.080 (0.011)	0.04	0.02	0.00

\*rounded to the nearest 50 thousand

In addition to estimation of harvest rates, we also used bandings and recoveries of \$100 reward bands to estimate the derivation of black duck harvests from the three breeding regions to the six harvest regions described by Conroy et al. (2004) (Fig 9). For this analysis, we tallied the proportion of an area's recoveries derived from each breeding region, with each recovery weighted by the number of birds represented by each band as determined by average of the population size from the Canadian Wildlife Service surveys.

Each of the harvest regions in Canada received the majority of their harvest from their respective breeding regions (Table 2). The harvest of birds in the Mississippi Flyway was derived almost exclusively from the western breeding region, but both the southern and northern portions of the Atlantic Flyway derived a mix of black ducks from all three breeding regions.

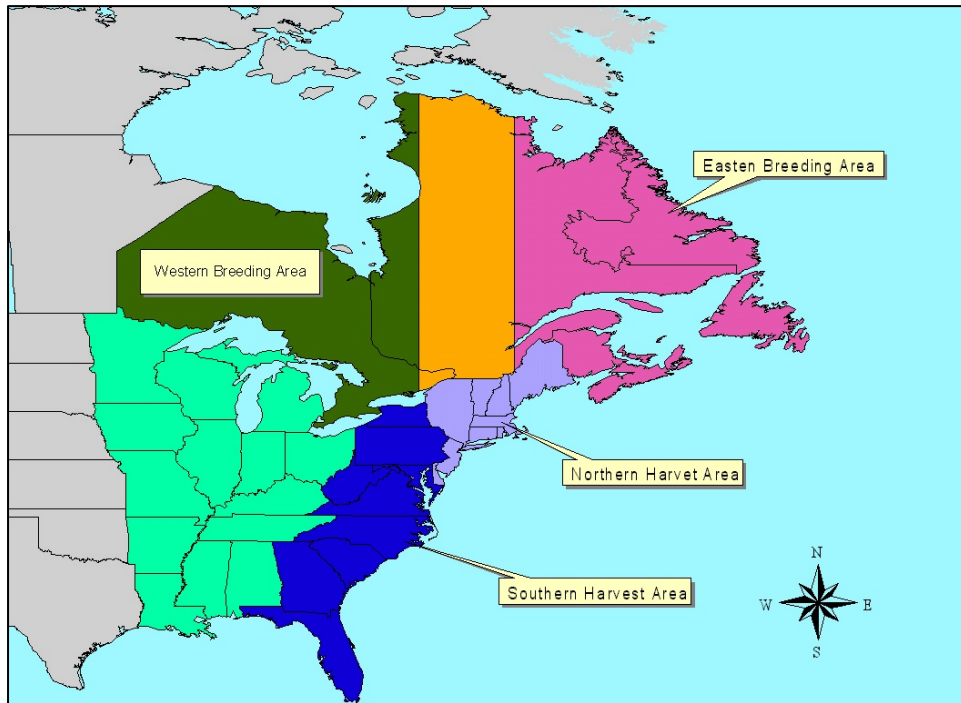


Fig. 9. Three black duck breeding regions in Canada and six harvest areas as defined by Conroy et al. (2004).

Table 2. Harvest derivation of black ducks based on reward banding during 2002-2004. Band recoveries were weighted by population size as estimated from the Canadian Wildlife Service breeding-ground surveys.

Harvest region		Banding region			total
		WEST	CENTRAL	EAST	
	banded	1215	1091	3780	6086
	average population	192000	141000	288000	621000
	birds/band	158.02	129.24	76.19	
Western Canada	recoveries	59	3	1	63
	percent	95.26	3.96	0.78	100.00
Central Canada	recoveries	4	104	20	128
	percent	4.05	86.18	9.77	100.00
Eastern Canada	recoveries	11	22	336	369
	percent	5.76	9.42	84.82	100.00
Mississippi Flyway	recoveries	42	2	1	45
	percent	95.20	3.71	1.09	100.00
Atlantic Flyway South	recoveries	44	33	64	141
	percent	43.20	26.50	30.30	100.00
Atlantic Flyway North	recoveries	23	56	139	218
	percent	16.93	33.72	49.34	100.00

Finally, we estimated breeding and harvest-region specific harvest rates of adult and young black ducks based on pooled bandings and recoveries of reward bands during 2002-2004 (Table 3).

Table 3. Breeding and harvest-region specific harvest rates as based on reward banding of black ducks.

Age	Breeding region	Year	Harvest region						
			Western Canada	Central Canada	Eastern Canada	Mississippi Flyway	Atlantic Flyway South	Atlantic Flyway North	total
			h (se)	h (se)	h (se)	h (se)	h (se)	h (se)	h (se)
<b>Adult</b>	<b>West</b>	2002	0.023 (0.016)	0.012 (0.012)	0.000	0.058 (0.025)	0.012 (0.012)	0.000	0.105 (0.033)
		2003	0.007 (0.007)	0.000	0.000	0.020 (0.011)	0.007 (0.007)	0.013 (0.009)	0.047 (0.017)
		2004	0.016 (0.011)	0.008 (0.008)	0.000	0.008 (0.008)	0.008 (0.008)	0.008 (0.008)	0.048 (0.019)
		pooled	0.014 (0.006)	0.006 (0.004)	0.000	0.025 (0.008)	0.008 (0.005)	0.008 (0.005)	0.061 (0.013)
	<b>Central</b>	2002	0.000	0.036 (0.018)	0.000	0.000	0.045 (0.020)	0.027 (0.015)	0.108 (0.030)
		2003	0.000	0.030 (0.015)	0.008 (0.008)	0.000	0.030 (0.015)	0.045 (0.018)	0.113 (0.028)
		2004	0.005 (0.005)	0.032 (0.012)	0.009 (0.006)	0.005 (0.005)	0.009 (0.006)	0.032 (0.012)	0.091 (0.020)
		pooled	0.002 (0.002)	0.032 (0.008)	0.006 (0.004)	0.002 (0.002)	0.024 (0.007)	0.035 (0.008)	0.102 (0.014)
	<b>East</b>	2002	0.000	0.005 (0.003)	0.025 (0.008)	0.000	0.005 (0.003)	0.025 (0.008)	0.060 (0.011)
		2003	0.000	0.004 (0.004)	0.036 (0.012)	0.000	0.012 (0.007)	0.045 (0.013)	0.097 (0.019)
		2004	0.000	0.000	0.036 (0.012)	0.000	0.016 (0.008)	0.036 (0.012)	0.087 (0.018)
		pooled	0.000	0.003 (0.002)	0.031 (0.006)	0.000	0.010 (0.003)	0.033 (0.006)	0.077 (0.009)
<b>Young</b>	<b>West</b>	2002	0.063 (0.013)	0.003 (0.003)	0.000	0.054 (0.012)	0.054 (0.012)	0.026 (0.008)	0.199 (0.021)
		2003	0.100 (0.021)	0.005 (0.005)	0.010 (0.007)	0.015 (0.009)	0.045 (0.015)	0.030 (0.012)	0.204 (0.028)
		2004	0.040 (0.011)	0.000	0.030 (0.010)	0.036 (0.011)	0.043 (0.012)	0.017 (0.007)	0.165 (0.021)
		pooled	0.063 (0.008)	0.002 (0.002)	0.013 (0.004)	0.039 (0.007)	0.048 (0.007)	0.023 (0.005)	0.188 (0.013)
	<b>Central</b>	2002	0.000	0.149 (0.026)	0.010 (0.007)	0.000	0.036 (0.013)	0.082 (0.020)	0.277 (0.032)
		2003	0.000	0.095 (0.020)	0.033 (0.012)	0.000	0.038 (0.013)	0.057 (0.016)	0.223 (0.029)
		2004	0.009 (0.006)	0.180 (0.026)	0.045 (0.014)	0.005 (0.005)	0.032 (0.012)	0.054 (0.015)	0.324 (0.031)
		pooled	0.003 (0.002)	0.142 (0.014)	0.030 (0.007)	0.002 (0.002)	0.035 (0.007)	0.064 (0.010)	0.275 (0.018)
	<b>East</b>	2002	0.000	0.005 (0.002)	0.115 (0.010)	0.000	0.015 (0.004)	0.033 (0.006)	0.168 (0.012)
		2003	0.001 (0.001)	0.008 (0.003)	0.101 (0.009)	0.001 (0.001)	0.024 (0.005)	0.038 (0.006)	0.173 (0.012)
		2004	0.000	0.005 (0.003)	0.107 (0.011)	0.000	0.019 (0.005)	0.043 (0.007)	0.174 (0.014)
		pooled	0.000 (0.000)	0.006 (0.001)	0.108 (0.006)	0.000 (0.000)	0.019 (0.003)	0.038 (0.004)	0.172 (0.007)

Harvest rates were highest for black ducks banded in the central breeding region, followed by the eastern and western regions. Young black ducks tended to be 2-3 times as vulnerable to harvest as adults, a differential vulnerability that tended to be somewhat higher than that reported by Conroy et al. (2002).

### **The “Kingston Accord”**

A meeting of the Black Duck AHM Working Group was held in conjunction with the Black Duck Joint Venture technical and board meetings in November 2004 in Kingston, Ontario. The intent of this meeting was to summarize and discuss important findings and main conclusions from the final report by Conroy et al. (2004).

One of the issues of most concern to stakeholders throughout the development of an AHM approach for black ducks has been the question of spatial stratification as a means for dealing with potential variability in black duck population dynamics as well as in hunter socio-dynamics across the range of black ducks. Conroy et al. (2004) concluded (pages 222-223):

“Spatial AHM is appealing as an approach for integrating biological knowledge about different stocks of black ducks into a model for setting regional harvest regulations for black ducks. The reality is that much of this touted ability is presently elusive, for at least 2 reasons. First, as elaborated above, our ability to build spatial AHM models for black ducks may have gotten ahead of our ability to parameterize them. Thus, one may very well be able to construct optimal harvest models with specified functional and parameter values, but currently some components of these models do not behave in a biologically reasonable manner. Unless critical parameters of these models can be updated as new information is available, it is a dubious proposition to base long-term harvest strategies on these models, unless it can be revealed that the strategies are insensitive to these parameter values or functional relationships. Second, even if computational challenges of these highly-dimensional problems can be overcome, our analysis makes clear that some types of spatial harvest strategies, and some combination of constraints, are not helpful to resolving the question of “what is the optimal harvest strategy over space and through time?” While attractive, and apparently globally optimal, spatially unconstrained harvest strategies are non-unique. That is, there are many different strategies that achieve the same maximum objective value, including the one selected by ASDP.”

Conroy et al. (2004) further concluded (page 8):

“Although an ultimate goal of this project is to develop and evaluate spatially-stratified models, most of the modeling to date has been for a single, continental population. This work, notably the models summarized in the monograph by Conroy et al. 2002, is thus a natural first step for further, possibly more complex models. In addition, a number of technical challenges exist to the parameterization and use of spatially-stratified AHM models. These include, at a minimum: (1) absence of data to suitably parameterize and update such models, (2) complexity and difficulty in deriving optimal harvest strategies, and (3) difficulties in displaying, explaining and interpreting highly-dimensional model results. In addition, spatial stratification is but one relevant “layer” of complexity to be

considered, in that issues of integration of AHM across species (particularly relevant for black ducks and mallards in the East), and connection of harvest and habitat management decisions and objectives, remain elusive. While not necessarily an endpoint in the development of an AHM process for black ducks, a single-population approach is a critically important and necessary foundation.”

Finally, the Conroy et al. (2004) observed: (page 216):

“Results from the single-population models (Chapter 2) have already begun to contribute to AHM for black ducks. First, an examination of historical harvest rates in relation to harvest rates that “would have been optimal” if AHM had been in place, has placed historical and recent harvest regulations in perspective. Generally speaking, these analyses have suggested that harvest of black ducks has not been overly exploitive, and has, on average, come close to what would have been recommended, had AHM been in place. Second, the existing AHM models provide guidance for interim harvest strategies that are based on adaptive principles. Third, although AHM for black ducks probably will be based on surveys of breeding populations in the long term, the MWS [i.e., midwinter inventory] continues as an alternative means of monitoring overall population status. Therefore, continental AHM for black ducks could proceed based on these models, until such time as models based on breeding populations (including spatial stratification) are available and fully developed.”

Based on these findings, the Black Duck AHM Working Group agreed for now on a single-population approach to the harvest management of black ducks, but with the understanding that the conversion to models based on breeding-ground surveys would be made as soon as possible. Recently, the Black Duck Joint Venture provided funding to Mike Conroy to attempt this conversion, under a Research Work Order with the following objectives:

- 1) complete statistical analyses for a single-population model based on Canadian plot-survey data, band recovery, and harvest data; specifically, this will involved using Markov Chain Monte Carlo or other methods to estimate coefficients of the projection models under alternative hypotheses of mallard competition and harvest compensation, estimates of “correction factors” for biases in model predictions, and estimates of environmental stochasticity; and
- 2) incorporate estimates obtained under 1) in revised dynamic-programming code, which will then be used to develop optimal state-specific harvest rates for black ducks.

This modeling approach will facilitate the incorporation of integrated breeding-population estimates from all survey protocols within the range of black ducks (M. Koneff, pers. comm.), and will permit spatial stratification of breeding populations should it become feasible in the future.

The product of this new research is intended to be optimal harvest rates for Canada and the U.S., designed to maximize long-term cumulative harvest, conditioned on:

- 1) an agreed upon a population goal, and a method for devaluing harvest for those management decisions that result in populations below goal; and
- 2) approximate parity in harvest between the two countries.

It would then be the responsibility of the two federal agencies for allocating harvest opportunity within their respective countries to achieve the prescribed country-specific harvest rates.

A harvest strategy that helps maintain population size above some numeric goal has appeal, although there is not yet consensus on the magnitude of the goal, nor on the appropriate tradeoff between harvest and the goal as the population falls below goal. If a continental population goal is to be used, the original NAWMP goal of 385 thousand black ducks in the MWI (or its rough equivalent of 640 thousand in the CWS breeding-population surveys) may be an appropriate choice. It is worth noting, however, that the AHM Task Force recently noted that NAWMP population goals cannot be used easily in AHM processes until those goals can be interpreted within the context of “average” environmental conditions. The AHM Task Force and the NAWMP Committee recently established a joint task group to develop recommendations about how NAWMP goals should be interpreted for purposes of biological planning and evaluation in both harvest and habitat management.

Goals other than those of the NAWMP are being considered. The Black Duck AHM Working Group has recommended a continental population goal of 496 thousand black ducks, which is distributed among three breeding regions (Western – 175k; Central – 115k; Eastern – 206k). These goals represent average black duck abundances derived from the Canadian Wildlife Service surveys during 1996-99. However, these goals are not based on estimates of black duck numbers throughout their breeding range, and have yet to be vetted by the larger management community. They might also be interpreted as representing a retreat from efforts to rebuild historic black duck numbers.

The other constraint concerning harvest-management objectives involves spatial distribution of the harvest. Fortunately, there appears to be broad agreement that any harvest strategy should not disrupt the tradition of approximate parity in harvests between the U.S. and Canada.

In any case, the population models and optimization framework necessary to investigate the implications of these and other management objectives should be available by late spring of 2006.

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### **Literature Cited**

Beddington, J. R., and R. M. May. 1977. Harvesting natural populations in a randomly fluctuating environment. *Science* 197:463-465.

- Conroy, M. J., M. W. Miller, and J. E. Hines. 2002. Identification and synthetic modeling of factors affecting American black duck populations. Wildlife Monograph No. 150. 64pp.
- Conroy, M. J., C. J. Fonnesebeck, and N. L. Zimpfer. 2004. Development of an integrated, adaptive management protocol for American black ducks. Georgia Cooperative Fish and Wildlife Research Unit, University of Georgia, Athens. 296pp.
- Hilborn, R., C. J. Walters, and D. Ludwig. 1995. Sustainable exploitation of renewable resources. Annual Review of Ecology and Systematics 26:45-67.
- Lubow, B.C. 1995. SDP: Generalized software for solving stochastic dynamic optimization problems. Wildlife Society Bulletin 23:738–742.